AN ALPINE CRUST-BASIN.

1 : *Das geotektonische Problem der Glarner Alpen.* A. Rothpletz. Pp. vii+251, and Atlas. (Jena: Fischer, 1898.)

2 : *Geologische Alpenforschungen.* A. Rothpletz. I. Pp. viii+176. (Munich: J. Lindauersche, 1900.)

A MORE than ordinary interest attaches to these two works by Prof. Rothpletz, as they treat of the boundary district between the Eastern and Western Alps. This district is already famous in geology, and has attracted all comers by its problems. My own opinion regarding its structure had been formed while I wrote my paper on the "Torsion-structure of the Dolomites" in 1898, and was given by me at the British Association Meeting and at the International Geographical Congress in 1899. I then compared the structure of this district with that of the areas of inthrow of various sizes that I had studied in the Dolomites. I described the Glarus-Prättigau area as a local area of depression or crust-basin within the Alps, around which fold-arcs had formed peripherally. Thrust-masses, taking origin in the peripheral arches, had moved towards the centre of the basin. And as across this area of depression the Alpine wave-movement of compression had also passed, the leading strike-curve of the Alps had been superinduced upon the local curves, making various angles with those, so that the actual crust-forms now presented to us were resultant combinations of the local movements round the subordinate basin, with the more extended Alpine movements round the North Italian crust-basins.

Our knowledge of the geology of this district has been vastly extended by Prof. Rothpletz. The actual observations recorded in these works, the discovery of many leading fossils in rocks whose age had hitherto remained doubtful or been erroneously determined, the large number of geological sections and the geological maps, must be regarded as one of the most brilliant achievements in Alpine geology. Two gems of detailed geological mapping may be recommended for careful study, namely, the north-west part of the Glarus district and the fault-blocks of the Rhätikon: (1: Taf. xi., and pp. 166–185; 2: Taf. i., and pp. 69–90.)

In all the leading text-books, the plication of the Alps is referred to lateral compression having acted mainly from the south in the Eastern Alps and rather more from south-east in the Western Alps, hence the curvature of the Alpine strike. Overthrusts are said to have taken place chiefly towards the north on the north side of the central chain, and towards the south on the south side. Glarus, on the north of the central chain, offered an exception to this rule, as according to Prof. Heim's epoch-making work ("Mechanismus der Gebirge," 1878) there had been within Glarus the advance of overthrust masses both from the north and from the south during the last Alpine upheaval.

Prof. Rothpletz contended (1) the existence of an overthrust mass in the south of Glarus, and (2) the correctness of Prof. Heim's conception of a crushed "middle-limb," as theoretically necessary in the process of overthrusting Prof. Rothpletz advocated that the phenomena of overthrusts were akin to differential movements between fault-blocks ("Querschnitt durch die Ost-Alpen," 1894, and "Geotektonische Probleme," 1895). Prof. Rothpletz, in his latest work on Glarus, in 1898, recognises the presence of a thrust-mass in the south of the Glarus area, but treats it as a mass originally continuous with the large thrust-mass on the north (*cf.* p. 211), and concludes from his observations that the whole of this "Glarus thrust-mass" had travelled *from east to west*, a distance of about twenty-five miles from the Rhine valley to the Linth. The rocks that form the *base* of the thrust-plane comprise all the geological horizons from the older gneiss to Oligocene strata, and have been folded along a *curved* strike, east-west near the Linth Valley, but curving round a southern arc to N.E.–S.W. direction nearer the Rhine Valley.

In the south or "Vorderrhein" portion of the "Glarus thrust-mass" the prevailing strike is N.E.–S.W. In the northern portion the rocks of the thrust-mass are folded along a curved strike, curving from S.S.W.–N.N.E. in the vicinity of the Linth Valley round a northern arc to an east-west strike.

In both the basal mass and the overthrust mass the folds have been overcast to the north and north-west, the compression of the folds having been very much stronger in the south than in the north. As many as ten folds overlie one another in the basal mass at Brigelser Horn, and are surmounted by a twisted portion of the thrust-mass with strike veering from S.W.–N.E. to S.N. This curvature is explained by Prof. Rothpletz as probably due to the local resistance offered by two eruptive masses (p. 160).

Three higher tiers of thrust-masses are present on the west of the Linth Valley in the Glärnisch Mountain; two of these thrust-masses continue in curved direction northeastward to the Schild Mountain and Lake Walen. The names given to them by Prof. Rothpletz are the Schild, Urner and Schwyz thrust-masses. Prof. Rothpletz says these masses have travelled from the north-west, but he expressly states his opinion that they advanced subsequently to one another and subsequently to the advance of the Glarus mass from the east, or locally south-east (p. 216).

Looking now at the second work, which treats of the east side of the Rhine Valley, the most important result is the description of a Rhätikon and Silvretta overthrust from the east. Prof. Rothpletz proves that the rocks of the Rhätikon Chain rest on a basal mass which is the natural continuation of the Glarus thrust-mass eastward, and he concludes that the Rhätikon mountain mass travelled from the Montafon Valley to the Rhine Valley, about nineteen miles from east to west. Tracing the origin of this thrust southward, he finds the rocks of the Silvretta Massive have been thrust eastward above the basal mass of the Prättigau, and still farther south the overthrusts are continued in the Lenz and Oberhalbstein mountain-group. The independence of the over-thrusting and the folding processes may, in Prof. Rothpletz's opinion, be concluded from the fact that the direction which has been followed by the thrust-mass frequently makes an angle with the strike of the folds. He attributes the difficulties which have hitherto attended the solution of the geological problems here :—

(1) Partly to the fact that all these overthrust masses and the basal mass in the district of the Glarus and Rhätikon have been pushed subsequently towards the north-west above the folds in the outer, or "molasse," zone of the Alps; thereby the original inclinations of the several thrust-planes have been altered or masked. (2) Partly to subsequent displacements effected along longitudinal and transverse fault-lines. (3) Partly also to the insufficient knowledge of the details of the stratigraphical succession as exhibited in the different facies of the Helvetic and the Austrian Alps.

What occurs to me in reading these works is that a great number of the observations which Prof. Rothpletz has given are unaccounted for in the conception of the structure as yet presented by that author. The conception does not go far enough, it misses the significance of the author's carefully collected data of strike and dip which prove intercrossing and curved strikes to be really the leading structural feature of the district. Prof. Rothpletz does not offer any explanation of that remarkable fault-curve in his map which follows the Linth Valley N.N.E. as far as the Schild Mountain, then curves east to the Sees Valley, and again S.S.E. and S.E. to Sargans; or interpret that other zig-zagging fault which curves round the south of the Rhätikon and south-east through the Falknis Chain, then southward in the Silvretta Massive, and again south-west through the Lenzerhorn Chain. According to my experience in the Dolomites, and having regard to the variations of the strike in the folds of the thrust-masses, I would consider these as primarily strike-faults through curved folds that formed round a local crust-basin (*cf. Geological Magazine*, 1894, pp. 54-58; *Q.J.G.S.*, 1899; *Geographical Journal*, 1900).

Let any one glance at my figure of the torsion-curves round the northern periphery of the Adriatic crust-basin (*L.C.*, 1899, fig. 22). The curves are convex to the north; the chief overthrusts have come from the W.N.W., N.W., N. and N.E., and have moved centripetally with reference to a centre in the Adriatic depression. Or compare the much smaller fold-arc of the Gröden Pass arch and its accompanying fault-curve from Plon over the Gröden Pass to Ruon and Corvara.

The arc of origin of the thrust is convex to the north; the thrust-mass has advanced southward and been broken up into several fault-blocks by faults, for the most part, transverse to the arc of origin. Return, now, to the map of the Glarus (Rothpletz's Atlas, Taf. xi.), and it will be clear that there is a repetition of similar geological phenomena. Even the details in the typical fold-forms are essentially alike (compare Rothpletz, Plate v., Figs. 5, 6, with sections 4, 5, 6 and 16, 17 in my "Torsion-structure.") In passing, it may be said that this similarity is in so far important, as it shows how much closer is the resemblance in the structure of the Eastern and Western Alps than has been usually supposed.

My interpretation of Prof. Rothpletz's data may now be indicated. His description of the continuation of the Glarus thrust-mass westward and eastward from the Mürtschen-Stock shows that it is broken by numerous faults along which both horizontal and vertical displacements have taken place, and that the typical fold-form has undergone quite different modes and degrees of compression in the several fault-blocks. From the Firz Stock in the east to the Linth Valley in the west one is presented with a series of uplifts and downthrows having the character of incipient folds, where arches and troughs are limited by steep septa or faults. The Mürtschen and Firz group is buckled into three main fault-blocks, the central of which is the highest, while the Schild group is depressed relatively to the eastern group, but within itself shows also a central upthrow flanked by downthrown blocks. The faults which have determined this cross-buckling are practically transverse to the local curvature of the strike. They therefore represent what I termed "radial" faults, or the fault-radii of a fold-arc (*Q.J.G.S.*, 1899, p. 604). This cross-blocking of a fold-arc demonstrates the action of horizontal pressures parallel with the direction of the curved strike, in addition to the action of horizontal pressures rectangularly to the fold-arc, and indicates that we have here *a system of local pressures complete in itself*.

I further note from Prof. Rothpletz's sections that the horizontal compression along N.W.-S.E. lines has been much stronger in the case of the Schild group than in that of the Mürtschen group (1: Taf. vii., Figs. 8, 15). The N.W.-S.E. strike represents the general Alpine strike at this part of the Alps, and it will be observed that in the Schild area the "Alpine" strike coincides, or is very slightly oblique, with the local strike, hence the resultant crust-deformation here represents the sum of two almost similarly-acting sets of pressures. Moreover, it is well known that the Alpine movements became rapidly less intense from west to east in this boundary district between the Western and Eastern Alps. The predominance of the N.E.-S.W. or "Alpine" strike in the basal mass of plastic strata, and the general overcasting to N. and N.W. of the folds, both in the basal mass and the thrust-mass, together with oblique overthrusting between the fault-blocks, seem to me conclusive evidence that the "Alpine" movements were not only subsequent to the formation of the fold-arcs, but also subsequent to the initiation of the N.N.W.-S.S.E. faults through the fold-arc (*cf.* footnote, *Q.J.G.S.*, 1899, p. 559).

Take, again, the Rhätikon thrust-mass in Prof. Rothpletz's map (2, p. 161). Faults virgate from Bludenz to W.S.W. and S.W., and cut the curved fault which separates the Rhätikon and the Falknis crust-blocks. These faults I take to have been originally fault-radii of a Rhätikon fold-arc formed round the north-east of the crust-basin. The overthrust of that mass has taken place in the main *from* this direction towards the south-west. Each fault-block in this thrust-mass is gently folded between the Montafon Valley and the Falknis, and a N.W.-S.E. strike is present in the Gorvion and other parts close to the Falknis Chain. This strike, together with the folding, indicates the action of horizontal pressures from the north-east; and the virgating group of faults across the Rhätikon indicates the action of horizontal strains parallel with the curved strike of the fold-arc, effecting transverse fractures in the sense of fault-radii of the arc. Hence there is in the Rhätikon evidence of a complete set of local phenomena of compression analogous in character to those which appear in the north-west portion of the Glarus-Prättigau crust-basin.

The Falknis block is an anticlinal block separated by curved strike-faults from the Rhätikon on the north and he Prättigau on the south, and cut by north-south faults. It shows, therefore, the general east-west strike and transverse fractures characteristic of the eastern Alps. The curvature of the strike in the west part of the Falknis Chain from east-west to north-west may, like the curvature of the fault at this part, be taken to signify a resultant or compensatory divergence due to the inter-crossing of the local and the east-Alpine strike. Similarly, at the east end of the Falknis, the east-west strike curves to the south-east. The Falknis fault-block is a replica of the Gröden Pass anticlinal fault-block. The east-west strike is the dominant strike of the Eastern Alps, trending to E.S.E. in South Tyrol. It is acknowledged to have been an ancient strike along which movements have recurred in various ages in the Eastern Alps, although during the Pliocene movement the horizontal compressions from north and south were much less intense in the eastern than in the western Alps. This fact expresses the chief difference which obtains between the structures on the east and the west of the Rhine Valley. The fold-arcs round the east of the Glarus-Prättigau crust-basin have not sustained the same degree of compression during the subsequent Alpine folding as those round the western periphery; neither have the horizontal pressures acted quite from the same directions, the Alpine pressures having acted across Glarus towards the N.W., and across the Prättigau and Rhätikon more towards the north.

The eastern thrust from the Silvretta Massive gives expression both to the horizontal compressions rectangular to the eastern fold-arc of the local crust basin, and to the horizontal strains acting along the strike of the Alpine curve. In the greater Alpine curve, just as in the case of the smaller curve of the local basin, the formation of radial uplifts and downthrows is determined by these tangential pressures. And it is this cross-system which is more particularly accountable for the diagonal N.N.W. and N.N.E. and transverse faults and thrust-fractures in the Alps.

In my interpretation the Lenzerhorn Chain represents fold-arcs on the south-east of the local basin. The curved strike veers here from north-east to west, and there are also fault-radii in N.N.W. direction. The oblique shearing that has occurred here is apparently stronger than in the Rhätikon, but not nearly so strong as in the Brigels and Vorderrhein Chain, which represents the southern fold-arc in the Glarus district. My inference is that the original Glarus-Prättigau crust-basin with its peripheral folds has been cut into two unequal halves by the development of the Rhine fracture during the later Alpine movements. The Rhätikon and the Glarus have been rent asunder at the north of a radial Alpine fracture. The regional Alpine movements have superinduced wider curves above the local curves and have affected the two halves of the basin with different degrees of intensity, so that the eastern half occupies a broader area from north to south than the more strongly crumpled western half.

Hence the ground-work of the structure in this region is based upon *intersecting fold-arcs*, and all the additional details supplied by Prof. Rothpletz can be adopted in the scheme of Alpine geology which I demonstrated in 1899 upon the basis of the "fold-arc" and the "unit-area of depression" surrounded by torsion-curves of strike (Report Intern. Geogr. Congr. Berlin, 1899). The science of geology finds itself, at the threshhold of this new century, entering upon a development of research in which advance can only be made if the student of earth-structures can bring to bear upon his observations a sound knowledge of the laws of higher mathematics, dynamics and physics. And, if I may make a forecast, it is that structural geology will be ere long grouped in our university curricula with these exact branches of science.

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THE ZOOLOGICAL RECORD FOR 1899.

The Zoological Record. Vol. xxxvi. Being Records of Zoological Literature Relating Chiefly to the year 1899. Edited by D. Sharp. (London: Gurney and Jackson, 1900.) Printed for the Zoological Society.

THE editor of this invaluable record is to be congratulated on its early issue, the present volume having been in the hands of the public during the first week in December. The amount of energy on his part necessary, in order to secure punctuality in the delivery of their quota of manuscript from twelve contributors, can scarcely be realised except by those who have undergone a similar experience. This early appearance of the volume is, however, in part due to the circumstance that the contributors are now instructed not to await the arrival of the whole of the year's literature, but to be content with as much as is to hand at the date when their manuscript is required. That this decision is a wise one there can be no doubt, for it is much more important to issue the record at as early a date as practicable, than it is to insist on its containing the whole available literature of the year to which it is specially devoted.

This leads naturally to the remark that some want of uniformity is noticeable with regard to the inclusion of portions of certain serials in each year's record. For instance, the fourth part of the volume of the *Proceedings* of the Zoological Society of London for each year is not issued till well on in the following year. Now we find that in the records of mammals and birds, the contents of this part are quoted in the year to which they nominally belong, while they are omitted in the reptile and fish records. It is not for us to discuss which plan is the better, but we do urge that strict uniformity in this respect should be insisted upon by the editor.

Nor is this the only instance in which that functionary does not appear to have his team sufficiently well in hand. As the record of insects is by the editor himself, we may take this as the model which ought to be strictly followed by all his subordinates. This record is preceded by a carefully written introduction, bringing into special notice the leading features in the year's work; the papers are numbered, and where a series of new species are described in any particular genus, they are collectively designated as such at the end of the paragraph. In the